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Innovation in Occupational Health And Safety Through Gamification to Improve Safety Compliance

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***Abstract*—** Occupational safety and health (OSH) is a critical aspect of the construction industry, particularly in transmission network construction projects that involve high-risk activities such as working at heights and operating heavy equipment. Despite the implementation of established safety standards, workplace accidents remain a major concern, largely due to unsafe actions performed by workers. This study aims to examine the effectiveness of gamification in improving safety compliance at PT Surveyor Indonesia, Surabaya Branch, specifically in transmission network construction projects. This research employs a quantitative, descriptive-correlational design. Data were collected using a Critical Behavior Checklist (CBC) to record unsafe actions and a questionnaire to measure workers' perceptions of gamification elements. The gamification application was tested for one month. The results indicate that gamification was effective in significantly reducing unsafe actions, from 69% before implementation to 24% after implementation. The paired-sample t-test results show a significance value (2-tailed) of 0.000, indicating a statistically significant difference in safety compliance levels before and after the implementation of gamification. Furthermore, the findings demonstrate that gamification elements such as point systems, rewards, and leaderboards enhance worker motivation and engagement in adhering to safety procedures, thereby reducing unsafe actions. This study contributes to occupational health and safety practices by providing empirical evidence that gamification can serve as an innovative and effective strategy to improve safety compliance in high-risk construction projects.

Keywords—Behavior-Based Safety, Critical Behavior Checklist, Unsafe Action

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I. INTRODUCTION

Occupational safety and health (OSH) is a fundamental aspect that must be prioritized in the construction industry, particularly in transmission network construction projects [1], [2]. These projects involve high-risk activities, including working at heights, operating heavy equipment, and exposure to hazardous environmental conditions such as extreme weather and unstable structures. Despite the implementation of comprehensive safety standards, occupational accidents remain a significant issue in this sector.

Based on occupational accident data reported by BPJS Ketenagakerjaan, the number of work-related accidents in the construction sector has increased significantly in recent years. In 2022, a total of 1,363 occupational accidents were recorded, rising to 2,971 in 2023 and 4,233 in 2024. Most of these accidents are attributed to unsafe actions performed by workers, even though the working environment generally complies with established safety standards.

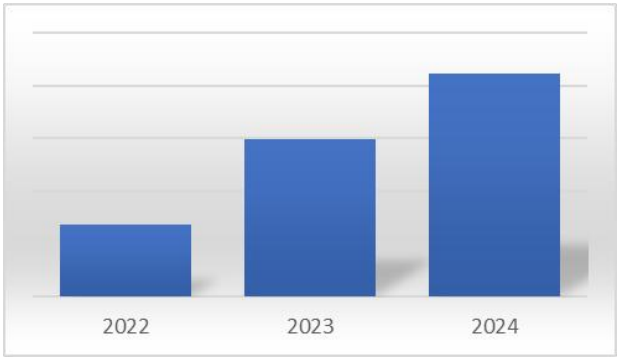

Figure. 1. Construction Work Accident Data from BPJS Ketenagakerjaan

Unsafe actions are behaviors that have the potential to cause occupational accidents, injuries, or even fatalities, either to workers themselves or to other workers in the workplace [3], [4]. Common unsafe actions observed in the field include non-compliance with safety procedures, improper use of personal protective equipment (PPE), failure to use PPE as required, and the deliberate neglect of established occupational safety procedures.

Data obtained from PT Surveyor Indonesia, Surabaya Branch, indicate that unsafe actions occur more frequently than unsafe conditions. In 2022, a total of 49 unsafe actions were recorded, compared to 33 unsafe conditions. This finding suggests that workers tend to engage in risky behaviors more often than they are exposed to hazardous working conditions. In 2023, the number of unsafe actions increased to 55 cases, while unsafe conditions also rose but remained lower, at 36 cases. A similar trend was observed in 2024, with unsafe

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actions reaching 68 cases, whereas unsafe conditions whereas unsafe conditions increased to 43 cases.

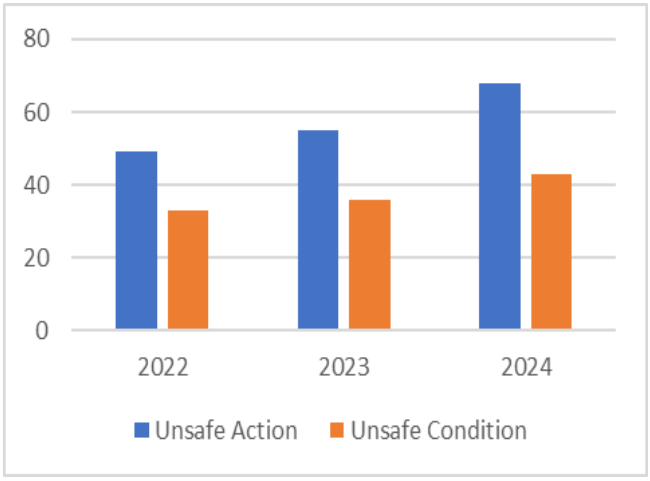

Figure. 2. Unsafe Action and Unsafe Conditions at PT Surveyor Indonesia (2022-2024)

Interviews with Reza Mega Setiawan, HSE Supervisor at PT Surveyor Indonesia, Surabaya Branch, revealed that risky behaviors frequently occur in the field. These behaviors include smoking during working hours, failing to use required personal protective equipment (PPE), and failing to attach safety harnesses to anchor points while working at heights. These findings highlight the importance of implementing more innovative approaches to reduce unsafe actions. One potential approach to minimizing unsafe actions is to apply gamification to occupational safety programs.

Figure. 3. Work Failing to Attach a Full Body Harness to the Anchor Point While Working at Height

One innovative approach with significant potential to enhance worker engagement in occupational safety programs is gamification. Gamification integrates game elements such as point systems, rewards, challenges, and competition to encourage workers to comply with safety procedures in a more engaging, interactive way. Through gamification, workers not only feel recognized for their safe behaviors but are also more motivated to increase their awareness of workplace safety [5].

Previous studies have demonstrated the effectiveness of gamification in reducing unsafe actions. Ajaka reported that gamification in safety training significantly improves worker engagement, motivation, and safety awareness. Participants in the study showed greater acceptance of gamified safety training than traditional training methods, particularly valuing its collaborative, immersive, and awareness-enhancing aspects [6].

The implementation of gamification in occupational safety programs has also been shown to increase worker participation, as game elements foster healthy competition and provide rewards that enhance motivation to prioritize safety [7], [8]. Consequently, gamification can strengthen existing safety culture in a more engaging and challenging manner. However, at PT Surveyor Indonesia, Surabaya Branch particularly in transmission network construction projects conducted by the Project Site Team (PST) in Kalimantan (Sections 1, 2, and 3: Tayan–Sandai) and at the 150 kV Ambawang Substation no previous studies have examined the application of gamification to reduce unsafe actions in the transmission network construction sector.

Despite its potential, research on gamification remains limited, especially in high-risk transmission network construction projects. This study, therefore, addresses this gap by investigating the application of gamification as an innovative strategy to reduce unsafe actions in transmission network construction projects at PT Surveyor Indonesia. This approach is expected to contribute to creating a safer, more proactive, and sustainable working environment through behavior change driven by gamification.

Accordingly, the objective of this study is to evaluate the effectiveness of gamification in improving safety compliance and reducing unsafe actions among

workers in transmission network construction projects at PT Surveyor Indonesia, Surabaya Branch.

II. METHOD

A. Research Approach

This study employs a quantitative research approach to examine the effect of implementing a gamification system on reducing unsafe actions in transmission network construction projects. The quantitative approach was selected because it allows for the objective, numerical measurement of relationships among variables and for statistical analysis to produce generalizable conclusions.

The quantitative approach is based on the positivist paradigm, which emphasizes the collection of objective data from a defined population or sample using structured research instruments and statistical analysis techniques [9]. In this study, the quantitative approach is used to test hypotheses regarding the effect of gamification on workers' unsafe actions.

B. Research Design

The research design applied in this study is a descriptive correlational design, which aims to describe and analyze relationships among variables without manipulating the research variables. This study examines the relationship between the implementation of a gamification system and the level of unsafe actions among workers in transmission network construction projects.

In addition, this study adopts a conceptual design for gamification implementation to enhance workers' motivation to comply with occupational safety procedures through elements such as point systems, rewards, leaderboards, and badges. The gamification system is not developed as a complex technical prototype but is applied as a measurable conceptual mechanism. The reduction of unsafe actions is assessed using a Critical Behavior Checklist (CBC) to observe and evaluate workers' safety behavior in the field.

C. Design Thinking

The Design Thinking method is employed as the framework for developing the gamification system in this study. Design Thinking is a user-centered approach that emphasizes user experience in the design of systems or solutions by considering functional, emotional, and interaction aspects [10]. This approach focuses not only on users' needs but also on their overall experience in interacting with the system [11].

Design Thinking consists of five iterative stages: empathize, define, ideate, prototype, and test. This method is relevant to the present study because it directly involves workers at each stage of gamification development, ensuring that the resulting system aligns with workers' needs, characteristics, and motivations related to occupational safety. The stages are described as follows:

1) Empathize
   At this stage, the researcher conducted direct observations and interactions with workers to understand the challenges in implementing occupational safety. Unsafe actions were identified through field observations using the Critical Behavior Checklist (CBC).
2) Define
   The define stage aims to formulate the main problem based on observations and interviews conducted during the empathize stage. The primary issue identified was workers' low motivation and inconsistent compliance with safety procedures, which contributed to a high frequency of unsafe actions.
3) Ideate
   At this stage, various solution ideas were generated to address the defined problem. Gamification elements such as points, levels, rewards, leaderboards, and safety challenges were designed to enhance workers' motivation and engagement in safe work behavior.
4) Prototype
   The prototype stage involved developing a conceptual gamification system that illustrates point accumulation mechanisms, safety mission completion, and worker ranking. This prototype serves as an initial representation of the gamification system that can be quantitatively evaluated.
5) Test
   The test stage involved implementing the gamification system among a group of workers in transmission network construction projects. This stage aimed to evaluate the effectiveness of gamification in increasing worker motivation and reducing unsafe actions. Data were collected through CBC observations, questionnaires, and brief interviews to assess changes in safety behavior and workers' perceptions of the gamification system.

The following diagram illustrates the research framework, including the stages of the design thinking method:

D. Research Location and Time

This study was conducted at PT Surveyor Indonesia, Surabaya Branch, which provides construction management consultancy services for power plant and transmission network projects. The research locations included the Project Site Team (PST) Kalimantan, covering Sections 1, 2, and 3 (Tayan–Sandai), as well as the 150 kV Ambawang Substation in Pontianak, West Kalimantan. The study was conducted in December 2025.

The population refers to the entire group of objects or subjects that possess specific characteristics and serve as the data source for a study [9]. In this research, the population consists of all supervisors and safety-related workers involved in construction management consultancy projects for power plants and transmission networks in the PST Kalimantan area, managed by PT Surveyor Indonesia, Surabaya Branch. The total population comprised 141 workers, distributed across several project locations, as presented in Table 1.

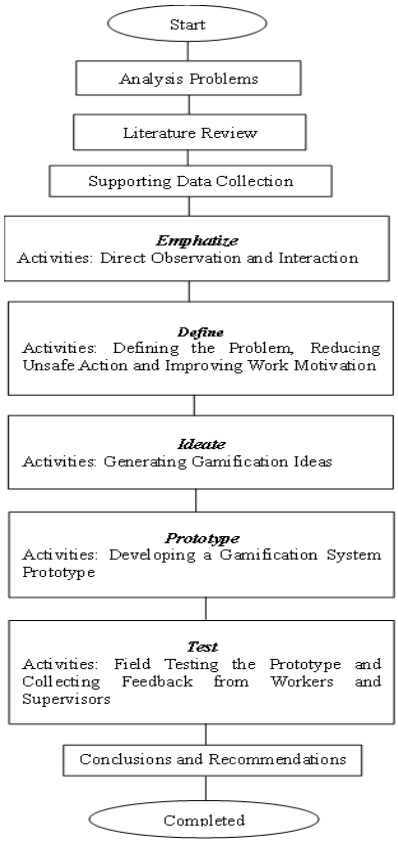

Figure 4. Research Flow

TABLE 1.
POPULATION DISTRIBUTION

No.	Location	Total workers
1.	Section 1	46
2.	Section 2	22
3.	Section 3	50
4.	Substation	23
	Total	141

A sample is a subset of the population that represents its characteristics [9]. This study employed a non-probability sampling method, in which not all members of the population have an equal chance of being selected [12]. The sampling technique used was purposive sampling, in which respondents were selected based on specific criteria relevant to the research objectives, particularly workers directly involved in high-risk construction activities and exposed to unsafe practices.

The sample size was determined using the Slovin formula, which is commonly used to calculate the minimum sample size in studies with relatively large populations and a defined error tolerance [9]. This approach ensures that the selected sample proportionally represents the population.

$$n = \frac{N}{1+N(e)^2}$$

$$n = \frac{141}{1.353}$$

$$n = 104.2 \cong 104$$

Based on the Slovin formula, the final sample size in this study consisted of 104 respondents.

E. Data Analysis Techniques

Data analysis in this study employed statistical methods to evaluate the effectiveness of the gamification system in reducing unsafe actions among workers in transmission network construction projects. The analysis focused on comparing levels of unsafe actions before and after the implementation of gamification as a safety intervention.

1) Normality test

Before conducting further statistical analysis, a normality test was performed to determine whether the unsafe action data were normally distributed. The normality test is a prerequisite for applying parametric statistical tests, such as the paired-sample t-test. In this study, data normality was assessed using the Kolmogorov–Smirnov test. The data were considered normally distributed if the Asymp. Sig. (2-tailed) value exceeded 0.05 [9].

2) Paired Sample t test

After confirming data normality, a paired-sample t-test was conducted to examine whether there was a statistically significant difference in unsafe action levels before and after the implementation of the gamification system. The paired-sample t-test was selected because it is appropriate for comparing two

related measurements obtained from the same group of respondents at different time points [13].

The test was performed at a 5% significance level (α = 0.05). A p-value of less than 0.05 indicates a statistically significant difference in unsafe action levels before and after the implementation of gamification. This analysis was used to determine the effectiveness of gamification as an intervention in reducing unsafe actions in transmission network construction projects.

II. RESULTS AND DISCUSSION

A. Result

1) Description of Respondents

Before conducting further analysis of the effect of the gamification system on reducing unsafe actions, the characteristics of the respondents were first examined. This analysis aimed to provide an overview of the respondents' demographic and professional backgrounds and to support a more contextually informed interpretation of the research findings. The respondent characteristics analyzed included gender, age, educational background, job position, length of service, and work location within the transmission network construction project.

TABLE 2.
RESPONDENT CHARACTERISTICS

Respondent Characteristics	Description	Frequency	Percentage (%)
Gender	Male	94	90
	Female	10	10
Age	20-25 years	18	17
	26-30 years	42	40
	31-35 years	26	25
	36-40 years	10	10
	> 40 years	8	8
Level of education	High School	8	8
	Associate's Degree	5	5
	Bachelor's Degree	88	85
	Master's Degree	2	2
	Other	1	1
Job title	Contractor	15	14
	Supervisor	89	86
Length of employment	< 2 years	60	58
	2-5 years	23	22
	6-10 years	15	14
	> 10 years	6	6
Work location	Section 1	34	33
	Section 2	16	15
	Section 3	31	30
	Substation	23	22

The results show that the majority of respondents were male, totaling 94 individuals (90%), while the remaining 10 individuals (10%) were female. This composition reflects the predominantly male workforce structure in the transmission network construction sector. In terms of age, most respondents were within the productive age range of 26–35 years. The largest age group was 26–30 years, comprising 42 respondents (40%), followed by those aged 31–35 years, with 26 respondents (25%). This age distribution indicates a workforce characterized by high mobility, strong work engagement, and good adaptability to innovation, including the implementation of gamification as a new approach to reducing unsafe actions.

Regarding educational background, the majority of respondents held a Bachelor's degree (S1), accounting for 88 individuals (85%). Respondents with a high school education (SMA) totaled 8 individuals (8%), those with a Diploma (D3) numbered 5 individuals (5%), and respondents with a Master's degree (S2) accounted for 2 individuals (2%). This educational profile suggests that most respondents possess sufficient academic capacity to understand occupational safety concepts and the gamification system applied in this study.

In terms of job position, most respondents (89 individuals, 86%) worked as supervisors, who play a direct role in overseeing and implementing occupational safety procedures in the field. Meanwhile, respondents working as contractors accounted for 15 individuals (14%).

With respect to length of service, the majority of respondents had less than two years of work experience, totaling 60 individuals (58%), indicating that most workers involved in the study were relatively new and potentially more vulnerable to unsafe actions. The remaining respondents had 2–5 years (22%), 6–10 years (14%), or more than 10 years (6%) of work experience, reflecting a range of experience levels within the sample.

Regarding work location, respondents were distributed across several areas of the transmission network construction project. Most respondents worked in Section 1, totaling 34 individuals (33%), followed by Section 3 with 31 individuals (30%), substations with 23 individuals (22%), and Section 2 with 16 individuals (15%). This diversity of work locations indicates varying levels of safety risk faced by workers, which is an important consideration in developing and implementing a gamification system tailored to the specific characteristics and risk profiles of each project area.

2) Normality Test

Normality testing was conducted to determine whether the research data were normally distributed, which is a prerequisite for applying parametric statistical analyses. In this study, the Kolmogorov–Smirnov test

was used to assess data normality in SPSS. The results indicate that the Asymp. Sig. (2-tailed) value was 0.200, which is greater than the significance level of 0.05. The results of the normality test are presented in Table 3.

TABLE 3.
NORMALITY TEST

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		104
Normal Parameters[a,b]	Mean	-.0242031
	Std. Deviation	10.84920548
Most Extreme Differences	Absolute	.060
	Positive	.039
	Negative	-.060
Test Statistic		.060
Asymp. Sig. (2-tailed)		.200[c,d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

3) R- Square test

The R-square (coefficient of determination) measures the extent to which independent variables in a regression model explain the variation in the dependent variable. A higher R-square value indicates a better model fit in explaining or predicting data variation. In this study, the R-square test was employed to evaluate the effect of gamification elements, such as points, levels, and rewards, on changes in unsafe action levels in transmission network construction projects. A high R-square value indicates that the regression model has strong explanatory power for the effect of gamification on reducing unsafe actions. In contrast, a low R-square value suggests weaker explanatory power.

TABLE 4.
R-SQUARE TEST

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.946[a]	0.895	0.894	1.211

The results of the R-square test indicate an R-square of 0.895, indicating that 89.5% of the variation in the dependent variable (unsafe actions) can be explained by the independent variables in the regression model, such as gamification elements (e.g., points, levels, and rewards). This high R-square value indicates that the regression model provides an excellent fit for explaining the relationships among the variables studied. Furthermore, the adjusted R-square of 0.894 supports this finding, as it is only slightly lower than the R-square. The close correspondence between the R-square and Adjusted R-square values suggests that the inclusion of variables in the model does not result in overfitting, indicating that the model remains robust and relevant in explaining the influence of gamification on unsafe actions.

4) Paired Sample t-test

The paired-sample t-test is used to examine differences in mean values between two related groups or measurements taken at two different time points. In this study, a paired-samples t-test was used to compare unsafe action levels before and after the implementation of a gamification system in transmission network construction projects. This test assesses whether a statistically significant change in workers' safety behavior occurred following the application of gamification.

TABLE 5.
PAIRED SAMPLE T-TEST

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Sebelum - Sesudah	-19.462	19.720	1.934	-23.297	-15.627	-10.064	103	.000

The results of the paired-sample t-test indicate a statistically significant difference in unsafe action levels before and after the implementation of the gamification system. The obtained Sig. (2-tailed) The value was 0.000, which is lower than the 0.05 significance level. This result demonstrates that implementing the gamification system has a statistically significant effect on reducing unsafe

actions. In other words, there is strong empirical evidence to conclude that gamification is effective in improving workers' safety behavior and reducing occupational accidents caused by unsafe actions in transmission network construction projects.

B. Discussion

1) Development of the Gamification System Using the Design Thinking Model

a. Empathize

The Empathize stage of the Design Thinking method aims to develop a deep understanding of the needs, behaviors, and safety challenges faced by construction workers in high-risk environments. In this study, the target users are workers directly involved in transmission network construction projects, who are routinely exposed to significant occupational hazards. Therefore, a systematic approach was employed to identify the main safety-related problems and workers' needs in efforts to reduce unsafe actions and improve occupational safety.

The Empathize stage emphasizes understanding workers' perspectives as system users through direct field observations and interviews to identify work behaviors, habits, and barriers to implementing occupational safety procedures [14], [15]. Observations were conducted at transmission network construction projects located in the Project Site Team (PST) Kalimantan area, covering Sections 1, 2, and 3 (Tayan–Sandai), as well as at the 150 kV Ambawang Substation. Work activities at these sites are dominated by high-risk tasks, particularly working at height and the use of mechanical work equipment.

Based on field observations, several unsafe actions were identified, indicating low levels of compliance with occupational safety procedures. Two major findings with the highest risk levels were selected as the primary focus at this stage.

Figure. 5. Worker Smoking and Operating a Grinder without a Safety Cover

Figure 5. illustrates a worker operating a grinder without a safety cover while smoking in the work area. This condition represents an unsafe action that significantly increases the risk of injury from grinding sparks and the potential for fire, especially in construction environments containing flammable materials. This finding reflects low worker awareness of occupational hazards, despite the availability of safety equipment and established safety regulations.

Figure. 6. Work Failing to Attach a Full Body Harness to the Anchor Point While Working at Height

Figure 6 shows a worker performing tasks at height on a transmission tower structure without attaching a full-body harness to the available anchor point. This unsafe action poses a very high risk, as it may lead to falls from height and result in serious injury or fatality. Such behavior indicates a tendency among workers toneglect safety procedures due to habitual practices, overconfidence, and the perception that using personal protective equipment (PPE) may slow work progress.

These observational findings were reinforced through brief interviews with HSE personnel and field workers. The interviews revealed that unsafe actions

often occur due to work target pressures, low risk perception, and inconsistent supervision. On the other hand, workers acknowledged their understanding of the importance of PPE use; however, its application in the field is often inconsistent, particularly during routine or seemingly low-risk tasks.

b. Define

After understanding the challenges workers face in the field during the Empathize stage, the Define stage in the Design Thinking approach aims to clearly and specifically define the core problem. The main issue identified in transmission network construction projects is the high level of unsafe actions taken by workers, despite established occupational safety procedures. Based on field observations and interviews with the HSE Supervisor, unsafe actions were found to be influenced by factors such as low motivation, entrenched work habits, and non-compliance with safety procedures.

These findings indicate that unsafe actions are primarily related to low adherence to safety procedures, limited motivation to follow safety standards, and inconsistent supervision, including incomplete use of personal protective equipment and failure to comply with work permit and fall protection requirements. This condition underscores the need for an intervention that focuses on behavioral change rather than relying solely on rule-based safety enforcement.

Therefore, gamification was identified as a potential solution to address these issues by enhancing worker motivation, engagement, and safety awareness through reward mechanisms, challenges, and feedback. By clearly defining the problem, this stage provides a strong foundation for designing a gamification-based safety system aimed at reducing unsafe actions and improving safety compliance in transmission network construction projects.

c. Ideate

The Ideate stage in the Design Thinking approach represents a phase of generating creative solution ideas based on insights obtained from the Empathize and Define stages. At this stage, solution development focused on addressing the primary issue identified in this study, namely, the high level of unsafe actions among workers in transmission network construction projects. Given the high-risk nature of the work and field workers' needs, a gamification-based safety system was conceptualized as an innovative approach to encourage behavioral change.

Several gamification ideas were developed, including a point-and-reward system for workers who comply with safety procedures, safety-related challenges or missions to promote sustained engagement, and leaderboards to foster healthy competition among workers. These elements were designed to enhance workers' motivation, safety awareness, and active participation in occupational safety programs. The ideas generated at this stage were subsequently selected and further developed during the Prototype stage to evaluate the effectiveness of gamification in reducing unsafe actions in the field.

d. Prototype

The Prototype stage in the Design Thinking method aims to turn the ideas generated during the Ideate stage into tangible and testable preliminary solutions. In this study, the Prototype stage was realized through the development of an occupational safety gamification system based on K3 (Occupational Health and Safety), named SI SAFE. This prototype was designed as a behavioral intervention tool to reduce unsafe actions and improve workers' compliance with safety procedures in transmission network construction projects.

The SI SAFE prototype was developed based on a K3 gamification point matrix that governs point allocation, mission types, and the forms of feedback provided to workers. The system integrates safety activities into daily, weekly, and monthly missions, enabling the formation of safe work behavior in a consistent and sustainable manner

Daily missions were designed to encourage routine compliance with occupational safety procedures. Each worker can earn a maximum of 20 points per day through four main missions:

(1) compliance with the use of Personal Protective Equipment (PPE),
(2) attendance at safety briefings,
(3) daily K3 field inspections, and
(4) job safety observations (JSO).

Each mission requires workers to upload supporting evidence, such as photos or documentation. Workers who complete missions according to the requirements receive points, while non-compliance earns no points. This scheme was designed to establish safe work habits through repeated reinforcement of positive behavior.

Weekly missions aim to enhance reflective and analytical safety awareness. There are three types of weekly missions: K3 quizzes, identification of unsafe actions and unsafe conditions (UA & UC), and implementation of 5R. These missions encourage workers to understand K3 materials, actively identify hazards in the field, and maintain cleanliness and order in the work area. The maximum total points that can be obtained from weekly missions is 50 points.

Monthly missions are designed to strengthen the safety culture through evaluative approaches and continuous improvement. These missions include safety meetings, closure and action on hazard findings, review of work permits and procedures, and K3 knowledge sharing. Through monthly missions, workers are not only required to comply with procedures but also to actively contribute to safety communication, follow up on hazard findings, and sharing of safety-related learning. The maximum total points for monthly missions is 80 points.

In this study, the occupational safety gamification system prototype was implemented as an SI SAFE Guide Book, serving as an implementation guideline for the K3 gamification system in transmission network construction projects. The SI SAFE Guide Book was designed to provide clear, structured guidance on the gamification mechanism, types of safety missions, the point system, and the system's usage flow for workers and supervisors. With this guidebook, the gamification implementation can be conducted consistently and easily understood by all users.

Figure. 7. SI SAFE Homepage

Figure 7 presents the cover page of the SI SAFE Guide Book, which serves as an introductory overview of the occupational safety gamification system. This page contains the system identity and the objectives of implementing SI SAFE in reducing unsafe actions and improving compliance with safety procedures. Figure 7 presents the cover page of the SI SAFE Guide Book, which serves as an introductory overview of the occupational safety gamification system. This page contains the system identity and the objectives of implementing SI SAFE in reducing unsafe actions and improving compliance with safety procedures.

Figure 8 shows the SI SAFE user registration page, which explains the account creation process for new users. At this stage, users are required to enter personal identity data in accordance with employee records to ensure data accuracy within the system.

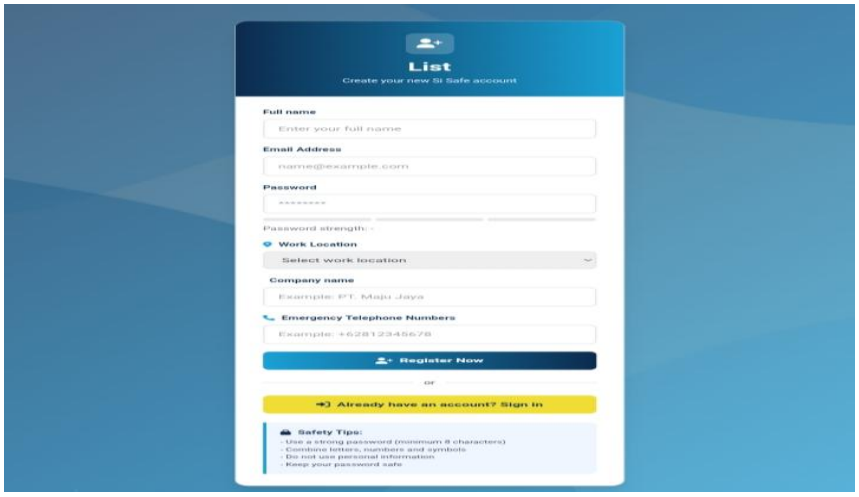

Figure. 8. Registration Page

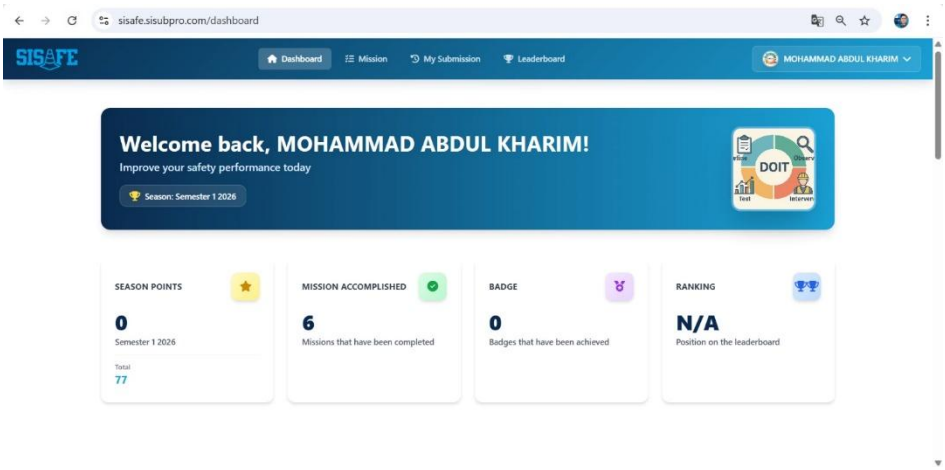

Figure. 9. Landing Page

Figure 9 illustrates the SI SAFE landing page after users successfully log into the system. This page serves as an information center that displays a summary of safety achievements, including total points earned, the number of missions completed, badges obtained, and the user's position on the leaderboard.

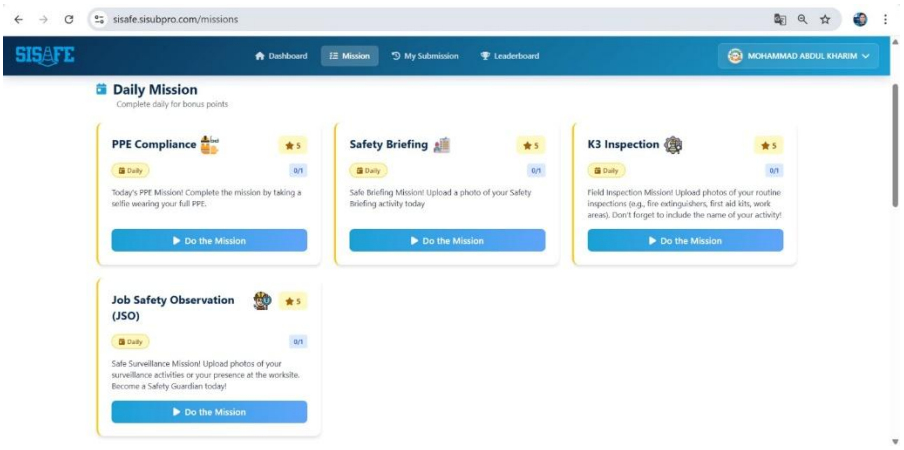

Figure. 10. SI SAFE Mission List Page

Figure 10. presents the SI SAFE mission list page, which contains a collection of safety missions that users must complete. Missions are categorized into daily, weekly, and monthly missions to gradually and sustainably establish safe work habits.

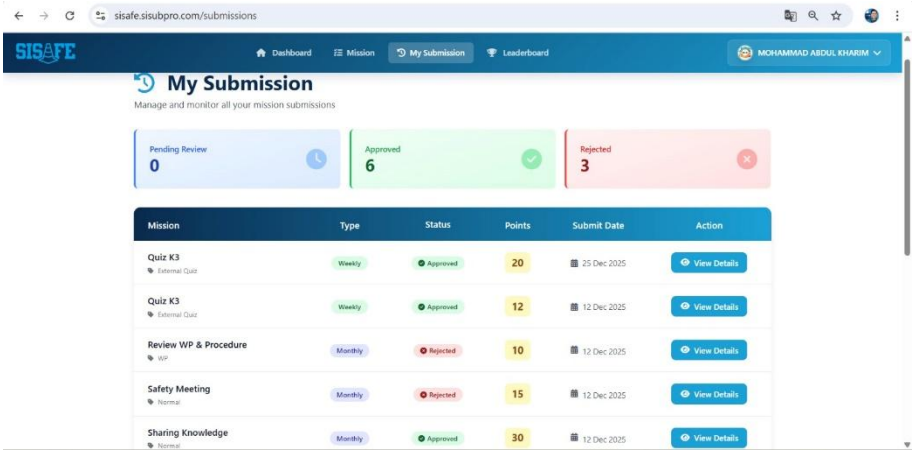

Figure. 11. SI SAFE Submission Page

Figure 11. displays the SI SAFE submission page, which allows users to upload evidence of mission completion, such as photos or other supporting documentation. Each submission is verified by an administrator or supervisor before points are awarded to the user.

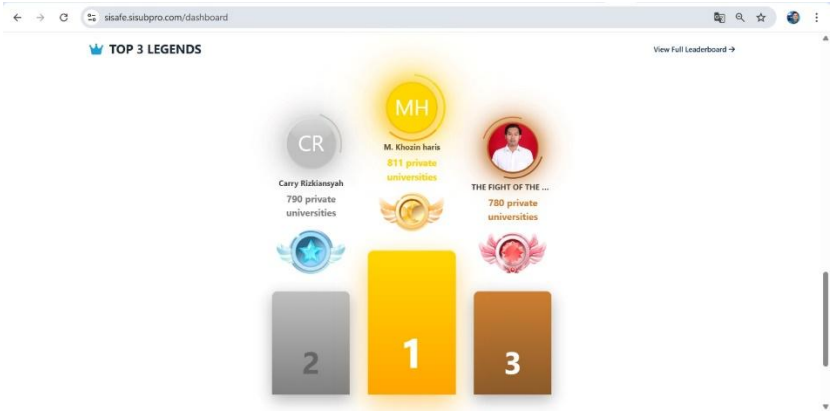

Figure. 12. Leaderboard SI SAFE

Figure 12. shows the SI SAFE leaderboard page, which displays user rankings based on total points earned. The leaderboard promotes healthy competition among workers and enhances motivation and consistency in carrying out occupational safety activities.

e. Test

The Test stage in the Design Thinking method aims to evaluate the effectiveness of the SI SAFE occupational safety gamification system prototype in addressing workplace safety issues identified during the Empathize and Define stages. The testing was conducted directly at several transmission network construction project sites over one month, with daily, weekly, and monthly safety missions implemented. These missions covered compliance with Personal Protective Equipment (PPE) use, K3 inspections, identification of unsafe actions and unsafe conditions, and follow-up corrective actions.

The testing results indicate that implementing the gamification system significantly increased workers' participation in occupational safety activities. This improvement is evidenced by the increased number of reports of unsafe actions and unsafe conditions, higher worker involvement in inspection missions and PPE compliance, and greater consistency in completing safety missions. The use of point systems, badges, and leaderboards encouraged workers to be more active and to adopt safe work behaviors, as safety was no longer perceived merely as an obligation but as an activity that provides recognition and appreciation.

Furthermore, the Test stage also demonstrated changes in workers' behavior patterns, particularly in high-risk activities such as working at height, where workers became more attentive to the use of PPE such as full body harnesses and safety helmets, as each compliance and safety finding directly affected point accumulation and performance evaluation within the system.

Using the SI SAFE gamification system, the implementation of safety missions carried out by workers during the test was tested, and data were collected. Figure 13. presents an example of a worker's mission completion results, showing a clear relationship between gamification mission implementation and efforts to reduce unsafe actions in transmission network construction projects. Most missions focused on controlling unsafe behaviors, such as PPE compliance, Job Safety Observation (JSO), K3 inspections, and safety briefings, were successfully completed and received approval. This condition indicates that workers not only followed safety procedures formally but also consistently applied safe work behaviors in their daily work activities.

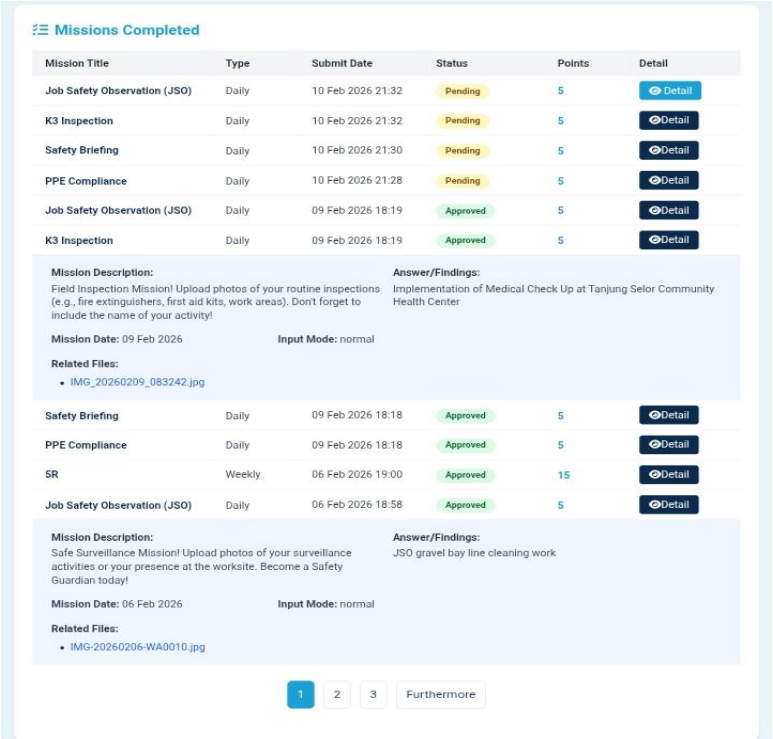

Figure. 13. Results of Mission Completion in the "SI SAFE" Gamification System

In addition, the development of gamification contributed to reducing unsafe actions through the use of the Report Per Location feature, as shown in Figure 14, which presents data on K3 mission submission activities by work location and specific time periods. The increase in the number of completed and approved missions indicates that workers have become accustomed to using the SI SAFE system to report occupational safety activities. This condition reflects increased reporting and follow-up actions related to unsafe acts and unsafe conditions, as well as improved worker compliance with safety missions, such as K3 inspections and PPE use. With the availability of structured, validated data, supervisors can objectively evaluate workers' safety behavior using reliable evidence.

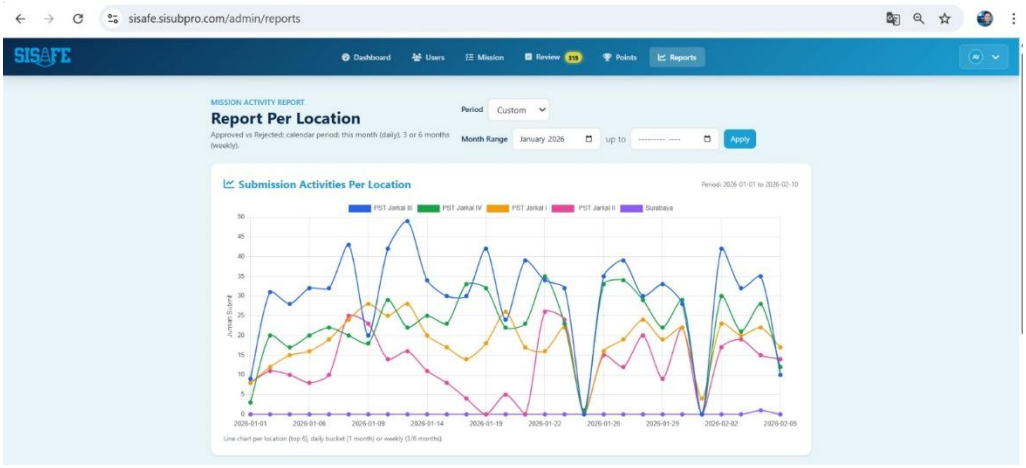

Figure. 14. Location-Based Report Results

Furthermore, the effectiveness of gamification development in encouraging behavioral change is reinforced by the utilization of the SI SAFE Leaderboard feature shown in Figure 15.

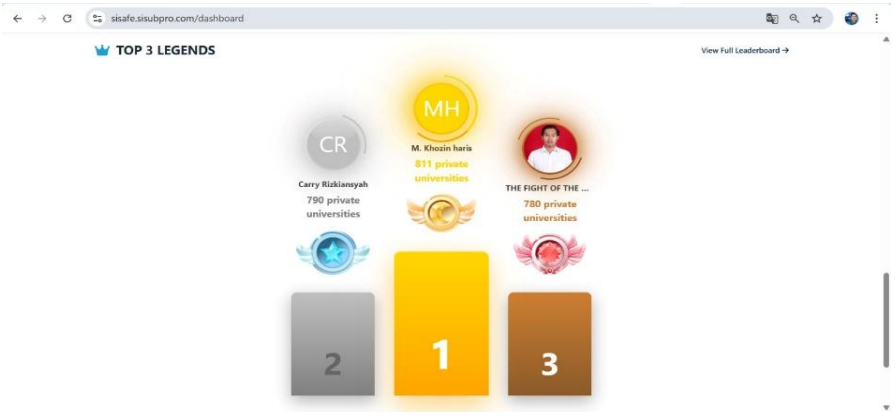

Figure. 15. Lederboard Results

The leaderboard displays worker rankings based on accumulated points obtained from verified K3 mission completions, thereby reflecting levels of participation, consistency, and compliance with occupational safety procedures. Differences in point accumulation among workers promote healthy and transparent competition, which indirectly motivates workers to be more disciplined in implementing safe work behaviors. Thus, the reduction of unsafe actions is reflected not only through increased system participation but also through consistent behavioral changes that become internalized in daily work activities.

1) Gamification Testing Using the Critical Behavior Checklist

The Critical Behavior Checklist (CBC) assessment in this study was conducted to evaluate changes in unsafe actions observed in the field before and after the implementation of the gamified occupational health and safety (OHS) system among workers in transmission network construction projects. CBC is an instrument used to identify at-risk work behaviors (unsafe actions) and safe behaviors in daily activities at project sites. The results of the CBC assessment provide empirical evidence regarding the effectiveness of gamification in motivating workers to improve compliance with safety procedures and reduce the risk of occupational accidents.

Before implementing the gamification system, the CBC results indicated that 69% of the observed behaviors were classified as unsafe, while only 31% were categorized as safe. This condition indicates that the majority of workers were still engaging in behaviors that could increase the likelihood of workplace accidents or injuries.

These findings are consistent with previous studies, which have reported that unsafe behavior is a dominant contributing factor to occupational accidents in the construction sector, where supervision and compliance with safety procedures are often suboptimal [16], [17]. Other studies have also shown that the promotion and implementation of OHS programs are significantly associated with reductions in unsafe actions in various industrial contexts, highlighting the need for effective interventions to motivate safe work behavior [18].

Following the implementation of the gamification system, the CBC results demonstrated a substantial behavioral change: the percentage of unsafe actions decreased markedly to 24%, while safe behaviors increased to 76%. This shift indicates that gamification positively influenced workers' safety behavior. The increase in safe behavior suggests that workers became

more motivated to follow proper safety procedures, such as using personal protective equipment (PPE), participating in safety briefings, and avoiding risky actions.

These behavioral changes align with findings from previous studies on gamification in construction safety management, which have shown that integrating game elements such as points, rewards, and challenges can enhance worker engagement in safety In addition, research on game-based learning approaches in construction safety training has demonstrated improved hazard recognition skills and stronger motivation for safe behavior compared to conventional training methods [21].

The significant reduction in unsafe actions following the implementation of gamification indicates that this approach not only raises safety awareness but also influences actual worker behavior in the field [22], [23]. This effect can be explained by the gamification mechanism, which provides immediate feedback and rewards for safe behavior. The system offers positive reinforcement through point-based rewards whenever workers demonstrate safe behavior or complete specific safety-related challenges. As a result, workers are more motivated to consistently engage in safe practices through a continuous rewards system.

2) Hypothesis Testing

In this study, regression analysis was employed to assess the effect of implementing a gamification system on unsafe actions in the transmission network construction sector. The coefficient of determination (R-Square) was used to assess the extent to which variations in unsafe actions could be explained by the independent variable, namely the gamification system. The analysis showed an R-Square of 0.89, indicating that 89% of the variation in unsafe actions can be explained by gamification. This value demonstrates that gamification has a very strong influence on reducing unsafe actions and improving occupational safety.

However, the R-Square value that does not reach 1.0 (100%) indicates that approximately 11% of the variation in unsafe actions is influenced by other factors outside the research model. These factors may include working environmental conditions, workers' physical conditions, work experience, and safety culture at the project site. Therefore, although gamification has been proven to have a significant impact, these external factors should be considered in future studies to obtain a more comprehensive understanding of occupational safety risk control.

These findings are consistent with the study by [24], which found that although gamification is effective in reducing unsafe actions, managerial support and a strong safety culture remain important in minimizing workplace accidents. In addition [25] concluded that the application of gamification elements in occupational safety can reduce accident rates and unsafe actions in the construction sector.

Furthermore, a paired sample t-test was conducted to examine differences in unsafe action levels before and after the implementation of the gamification system. The test results showed a significance value (sig. 2-tailed) of 0.000, which is lower than the established significance level of 0.05. This result indicates a highly significant difference between the conditions before and after gamification implementation, leading to the conclusion that the gamification system significantly reduces unsafe actions in the transmission network construction sector.

The significant reduction in unsafe actions indicates that workers became more compliant with safety procedures and avoided risky behaviors after engaging with the gamification system. This effect is strongly attributed to the gamification mechanism, which provides point-based rewards, missions, and incentives that increase worker motivation and engagement in occupational safety activities.

The results of this study are also consistent with those of [8], who reported that gamification in construction safety training is highly effective in improving safety awareness and reducing workplace accidents. Similarly, [26] found that gamification is an effective behavior-change mechanism that combines intrinsic and extrinsic motivation, thereby encouraging workers to comply with safety procedures.

Before implementing the gamification system, unsafe action levels were relatively high, indicating low worker compliance with safety procedures. However, after implementing gamification, the paired-samples t-test results showed a significant reduction in unsafe behaviors and an increase in safe behaviors. Therefore, it can be concluded that gamification not only reduces risky actions but also promotes the consistent adoption of safe work behaviors in the transmission network construction sector.

In addition to providing implications for the transmission network construction sector, this study's results also have strong relevance to the field of marine engineering. In the maritime industry, transmission networks and electrical systems play an essential role in supporting the operations of ports, shipbuilding facilities, and offshore electrical installations. The marine working environment shares similar risk characteristics with transmission network construction projects, such as working at height, the use of heavy equipment, and exposure to extreme environmental conditions. Therefore, the occupational safety gamification system developed in this study has the potential to be applied as an innovative approach to improving compliance with occupational health and safety procedures and strengthening safety culture in marine engineering projects.

.IV. CONCLUSION

This study demonstrates that implementing gamification in occupational health and safety management effectively reduces unsafe actions and improves safety behavior among workers on transmission network construction projects. The results of the Critical Behavior Checklist (CBC) and paired sample t-test indicate a significant decrease in unsafe actions and a corresponding increase in safe behavior following the application of the SI SAFE gamified system. Gamification mechanisms, such as missions, point-based rewards, and leaderboards, successfully enhanced worker engagement, motivation, and

compliance with safety procedures. These findings confirm that integrating gamification into formal safety management systems can serve as an effective behavioral intervention to strengthen safety culture and promote consistent safe work practices in high-risk construction environments. In addition to contributing to the transmission network construction sector, the findings of this study are also highly relevant to the field of marine engineering. Working environments in the maritime industry, including ports, shipbuilding facilities, and offshore electrical installations, share similar risk characteristics, such as working at height, the use of heavy equipment, and exposure to extreme environmental conditions.

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